

How can standards be developed that will be meaningful for radiation control? What guidelines are available? These and related questions are discussed in this paper which continues the analysis undertaken in the two preceding papers.

FEDERAL RADIATION COUNCIL GUIDES AND OTHER EXPOSURE STANDARDS

Alexander Grendon

IT is my intention to discuss the efforts of scientists, lawyers, administrators, and philosophers—indeed, of all interested people, qualified or not—to establish standards by which to say, “This much radiation is too much.” The obvious first question is, “Too much for what?” Too much for the health of an individual? Too much for a large population, no one of whom will run any great risk of harm but among whom some one or more may be injured by the exposure? Too much for the benefits gained by the process that produces the particular parcel of radiation? Too much to allow one person to impose, willy-nilly, on others? Too much for the genetic risk to people whom we will never see—the people of the world a hundred years hence?

The setting of standards is easiest where the only pertinent question is: Is this amount of the hazardous agent too much for the health of the individual exposed to it? We have had long experience in dealing with environmental hazards to which we have applied this test. One administers smaller and smaller doses of a toxic agent to several species of experimental animals until a level is found at which no adverse symptoms appear—a threshold. Then a factor of safety is applied and, behold! we have

a standard—for example, a maximum allowable concentration.

In the days when we were naive about radiation we followed exactly that practice. We found a dose that produced no apparent symptoms, lowered it by a factor of 10, and called it a tolerance dose on the assumption that the body tolerated it without harm. Then we ate of the fruit of the tree of knowledge and had to leave our Eden; for, “in the day ye eat thereof, then your eyes shall be opened.” We can carry the parable further; the story in Genesis says Adam hid from God, saying, “I was afraid, because I was naked.” And God said, “Who told thee that thou wast naked?” Today, our answer might be: The National Committee for Radiation Protection and Measurement, the Federal Radiation Council, the Women for Peace, the Committee for Nuclear Information, and so forth.

I do not mean to oppose the acquisition of knowledge. I do suggest that “a little learning is a dangerous thing” and that a fuller understanding of many of the other hazards of life, especially those created by our advances in science and technology, might lead us to abandon the threshold concept almost everywhere. Universal familiarity with the statistical risk concept that lies at the basis of our

present radiation exposure standards would help in maintaining perspective as to the relative importance of a whole spectrum of environmental hazards, among which radiation is only one.

Delayed Injury

Radiation happens to be the first environmental hazard so thoroughly studied as to disclose the fact that, even when no overt symptoms of injury appear, the submicroscopic biological changes it can produce may evolve in the course of time into observable damage. That characteristic is not unique to radiation, but it was first discovered there. We now know that there are very many substances in common use that possess this characteristic of inducing cancers—the carcinogens—or producing genetic mutations—the mutagens, and that commonly these two properties are associated. If we are to use this knowledge to set standards of exposure, we need to know the quantitative relation between dose and effect. For only one of these carcinogenic, mutagenic agents has the dose-response relationship been extensively studied, and that one is radiation.

Over the range of doses we have been able to study effectively, we generally find the response proportional to the dose. The doubtful region of investigation begins at dose levels where the response, in terms of production of mutations or tumors or of general debility that shortens the life span, reaches numerical values comparable to the normal incidence of these phenomena. For example, one widely accepted estimate of the risk of leukemia in man as a result of radiation exposure is one case per year per million persons for each roentgen of average exposure. Natural radiation exposure—the unavoidable background that comes from cosmic rays, uranium and thorium in the earth, potassium-40 in every bit of

the 140 grams of potassium in the body, radium in water and food, radon and thoron in the air—this exposure, for people in the United States, ranges from less than 0.1 roentgen per year to two or three times as much, depending on the altitude at which one lives, the kind of soil around us, the materials of which our houses are made, the foods we eat, the water we drink, and the activities we engage in. The difference between the extremes might be 0.2 roentgen of whole-body radiation per year and a slightly greater range for bone-marrow doses. Even if it were possible to find a million infants who could be made to stay put in each of these extremes of environment for the 20 years their skeletons are growing, to undergo no medical or dental irradiation, to eat artificially prepared foods that contained no fallout, and to check in regularly for examination during the following 10 to 20 years in which any difference in leukemia incidence might be expected to occur, the expected difference between the two groups on the basis of our hypothesis would be that about 80 cases per year would occur in the less irradiated group and about 84 in the more irradiated—an undetectable difference since “about 80” might mean 70 or 90 in any given year. Carol Buck has estimated that it would take a population of six million, followed for a ten-year interval, to reveal, on the average, a significant effect of a 5-roentgen dose if it exists at this level.¹

The difficulties are evident; but we cannot escape the dilemma of having to establish some rules of conduct. Everyone recognizes benefits associated with some forms of radiation exposure, so, clearly, it is not wise to say, “We will take no chances; radiation must go!” It would not be prudent, however, to take extravagant chances. To keep the risk within bounds that might, in some sense, be called “reasonable” must mean comparing this risk with others

we commonly and nonchalantly accept. Unfortunately, most of the other risks to health, safety, and life itself have never been put on a quantitative basis; and, to the extent they have been measured, the numbers may serve the purposes of actuaries but they have never been accepted by the general public as a guide to conduct. It takes a law—or a manufacturer's decision—to make most people put seat belts in their cars; and I do not know what it takes to make them use them. And just as people refuse to be concerned when statistics warn them of serious danger, they sometimes become excessively concerned when statistics indicate the risk is relatively low.

We were in a good position, by the mid-50's, to estimate an upper limit to the radiation hazard. The experimentally determined linear relation between dose and response could be extrapolated downward to doses a thousand, a million, or ten million times smaller than those we could effectively test. That is an enormous range of extrapolation, but at least it is on the safe side. There is good reason to think that, for many of the effects, the relation may continue down to the lowest doses; and there is no reason to expect a greater-than-proportionate response; hence, the hypothesis expresses a wise degree of caution.

Revised Philosophy by NCRP

That hypothesis first entered into our radiation protection standards to a modest degree when the National Committee on Radiation Protection and Measurements (NCRP) published statements of its revised philosophy in January, 1957, and April, 1958. There was no immediate, dramatic change in rules, since it was felt that the existing maximum permissible doses, established for control of the exposure of people whose occupations involved radiation, were safe enough in comparison with the

customary risks of hundreds of other occupations. The NCRP statement suggested that, because of the impact of the more restrictive standards on equipment and procedures and the nearly negligible risk in delay, five years time should be allowed for the transition.

The change in viewpoint did necessitate consideration of some new factors: a distinction between the small group of persons occupationally exposed to radiation and the larger group constituting the population living near atomic energy installations for whom lower limits are appropriate; prohibition of occupational exposure levels for young persons under the age of 18; reduction of the occupational limits as much as practicable, namely, by a factor of 3 for the most critical organs; and the need to keep a lifetime record of exposure if the maximum occupational limits were to be applied to any individual. The NCRP recommendations, as most of you know, have been published as a series of handbooks of the National Bureau of Standards. The 1954 edition of "Handbook 59" adopted the term "permissible dose" in preference to the former term, "tolerance dose," because, as they put it: "Since it seems well established that there is no threshold dose for the production of gene mutations by radiation, it follows that strictly speaking there is no such thing as a tolerance dose when all possible effects of radiation on the individual and future generations are included." The 1957 change extended this nonthreshold concept to somatic effects of radiation, and it reemphasized the NCRP's "long-standing philosophy that radiation exposures from whatever sources should be as low as practical."² There was still no set of numerical standards of exposure deemed allowable for the entire population of the nation; but the issue was becoming pressing because of the public concern about fallout from weapons testing.

The National Academy of Sciences

(NAS) had set up committees to study various phases of the radiation problem, and their first report was published in 1956. It is interesting, in the light of some of the intemperate and uninformed criticism sometimes directed at public agencies responsible for health and safety aspects of radiation, to quote from the foreword of that report: "The use of atomic energy is perhaps one of the few major technological developments of the past 50 years in which careful consideration of the relationship of a new technology to the needs and welfare of human beings has kept pace with its development. Almost from the very beginning . . . careful attention has been given to the biological and medical aspects of the subject."³ In this NAS report the genetics group recommended limiting the population average exposure, from all sources other than natural background, to 10 roentgens in the first 30 years of life. That 30-year figure is approximately the average age of parents at the times of birth of all children. The pathology group was less willing to commit itself to specific numbers; but it did express the view that an average body burden of radioactive strontium in the human race of such an amount as to give a lifetime dose of 20 rads to the skeleton was small enough that there was "no reason to hesitate to allow" it,⁴ since it was not much more than natural background and far less than the smallest doses observed to cause visible changes in the bone. When the National Academy updated its studies by another report in 1960, it reaffirmed the limits previously recommended for control of genetic risks and expressed the view that such limits would assure adequate control of the somatic risks.

Allowable Exposure

The one public agency that had a clear and immediate duty to announce

some official standards of allowable exposure was the AEC. By law, it had to license users of most radioactive materials and to inspect the conduct of their operations in the interests of public health and safety. Natural and social scientists may be willing to accept a broad zone as a boundary between desirable and undesirable courses of action; but a lawyer who sees the necessity of taking an offender into court and proving him a wrongdoer needs an unmistakable clear line between right and wrong. The AEC adopted the NCRP recommendations as its administrative law. It could scarcely have done better; but this necessary step gave many the belief that the legally permissible dose was thereby magically safe and 1 per cent above it was equally magically unsafe. The scientists who generated these standards recognized, of course, that they were faced with a problem that could not be solved with such mathematical precision. In the publications of the NCRP and its international counterpart, the International Commission on Radiological Protection (ICRP), there is frequent reference to the fact that their objectives were to set levels of allowable exposure that were practicable, in that they would permit the beneficial uses of radiation and radioactive materials to continue and expand, and yet would assure a very low risk of harm to individuals and to the population as a whole. The balancing of these opposed considerations can never be very exact; and the frequent use of the word "should" rather than "shall" in the rules proposed by the NCRP and ICRP is one index of that uncertainty. An administrative agency of government, however, generally has to make a decision whether to convert a "should" to a "shall" and thus make the requirement mandatory or to drop it entirely on the ground that it is too restrictive. Fortunately, most of those responsible for radiation safety in industry, research,

and elsewhere are willing to do many of the things they "should," even when no law says they "shall," so that the average exposure of those occupationally exposed to radiation is far below the maximum, and the average releases of radioactive materials to the environment are far below those permitted by the rules.

The ICRP and our NCRP have worked closely together in recent years. Not all the numbers designated as allowable levels of exposure or allowable concentrations of radioactive material in air or water are accepted as exactly the same in the two committees; but the differences are small and well within the limits of certainty of our knowledge. This unanimity of view is not surprising, of course, since our representatives in the international body are often members of the NCRP; but it is interesting to note that, despite the occasional allegations by people emotionally disturbed over fallout, for example, that "even the scientists disagree as to the effects of radiation," the disagreement is only in the fine details. The best informed experts of all nations have agreed more closely in these matters than in any other area of international relations.

There is, of course, no scientific way of deciding what is "appreciable bodily injury," a term formerly used by the ICRP in defining "permissible dose"; or "negligible probability of severe somatic or genetic injuries," as used in the current definition. The NCRP had some interesting comments on this problem in "Handbook 59," issued in 1954. They are worth presenting here:

"The only statement that can be made at the present time about the lifetime exposure of persons to penetrating radiation at [the] permissible level . . . is that appreciable injury manifestable in the lifetime of the individual is extremely unlikely. It is, therefore, necessary to assume that any practical limit of exposure that may be set up today will involve some risk of possible harm. The problem then

is to make this risk so small that it is readily acceptable to the average individual. . . .

"The acceptability of a risk by the average person depends largely on the probability of escaping injury altogether . . . for any given type and degree of injury there is an exposure level that will produce such injury only in the most susceptible individuals. . . . Accordingly, with a sufficiently low exposure level the probability of escaping injury altogether can be made very high. Because there is at present no way of determining in advance who is most susceptible to radiation, each person has, in effect, the same chance of escaping injury as anybody else. Under these conditions and in this sense, then, the risk of radiation injury has essentially the same characteristics as more common risks readily accepted by the average person in his ordinary pursuits."⁵

I should like to emphasize the individual's high probability of escaping injury entirely at the various permissible levels used in recent years, since this point seems to be frequently misunderstood. Even the respected ICRP, in its September, 1958, "Recommendations,"⁶ apparently fell into the trap in commenting on the supposed difference between "the two different types of possible long-term somatic effect that must be considered in setting up permissible limits of exposure." They described leukemia as "a serious effect occurring in some individuals" and contrasted it with the life-shortening effect, which "is presumably an effect on every individual." Nothing is known, or is ever likely to be discovered, that would support this view, that everyone loses a few days of life for each roentgen of wholebody radiation to which he is exposed. When, for example, Dr. Hardin Jones derived an estimate that the average life-shortening effect of 1 roentgen is five to ten days, it was based on life-span data of irradiated animals, some of whom died prematurely, but still of the customary ills of their species. If a thousand persons were given 1 r, perhaps one person, indistinguishable both before and after the fact, would die 20 years sooner than he would otherwise have died. Nothing marks his case as

unique; but that event can be said to be an average loss of 7.3 days of life for the group. Yet 999 would have suffered no harm, under these conditions, and the one victim would seem to be part of the normal mortality pattern. Even the leukemia deaths, if any, are part of this same pattern.

The uncertainty as to who, if anyone, pays the price of somatic injury is magnified when we try to determine who, among the many affected by our accumulated natural mutations over the centuries, is the victim of new genetic damage. Most mutations are recessive; that is, two defective genes governing the same bodily functions must meet in the conception of a child to bring out the defect. Since most of the defects thus produced are inconspicuous and even, in practical terms, insignificant, it is a rare event to find the mating of defective genes that produces a serious abnormality. It may occur many generations after the event that produced one of the defective genes, whether it be ionization by radiation or the action of some chemical agent or heat. If the cost in harm assessable against that event is paid by anyone, perhaps it can best be said to be paid by everyone.

The diffuseness of the risks and benefits that come from allowing and, in fact, encouraging advances in atomic energy and radiation gives the question of control certain aspects that can best be handled at the national level. The ICRP took note of the fact that peculiar national interests made it desirable to avoid international standards in some respects; and our federal government has seen fit to reserve certain areas of control for itself, even while surrendering to the states some of the powers it preempted because of the wartime birth of atomic energy. In recognition of the fact that the setting of radiation standards involves judgments beyond the domain of science, a federal statute established in 1959 an advisory group com-

posed of some of the President's cabinet-level aides—the Federal Radiation Council (FRC). The current chairman of the AEC, who is a statutory member of the FRC, happens to be a distinguished scientist, but the four cabinet members who constitute the rest of the council are not. To carry out its assigned duty of advising the President "with respect to radiation matters, directly or indirectly affecting health, including guidance for all Federal agencies in the formulation of radiation standards,"⁷ the council has to rely on the staffs of scientists within the government and on nongovernmental consultants. The body of scientific competence drawn upon for this purpose does not differ greatly from the personnel of the various committees previously mentioned, nor could it differ greatly, in view of the comparatively small number of recognized experts in the appropriate scientific fields. The interesting change is that the views and conclusions of the scientists are filtered through a group of nonscientists before being presented as recommendations to the President.

The first staff report of the FRC, published in May, 1960, dealt with basic radiation protection standards applicable to the normal "peacetime uses of radiation which affect the exposure of the civilian population." The council reviewed this report and prepared a memorandum to the President incorporating the key points of its findings in the form of a series of recommendations, which the President formally approved. This Report No. 1 and the corresponding recommendations are fundamental to an understanding of subsequent utterances of the FRC and its chairmen, so it must be studied carefully.

New Concepts

The "Memorandum for the President"⁸ introduced several concepts that were new to the area of formal admin-

administrative controls. These new elements all contributed flexibility that was appropriate to a document designed for guidance in developing administrative regulations, though almost certainly inappropriate in the regulations themselves, for practical reasons of enforcement difficulty.

The memorandum introduced the term "radiation protection guide" as a substitute for the previously used "tolerance dose" and "maximum permissible dose." "Tolerance" suggested that the body tolerated that dose without effect; "maximum permissible" suggested that under no conditions could a larger dose be allowed and, at the same time, however trivial the reasons for exposing persons to that dose, it was nevertheless "permissible." The memorandum recommended that "there should not be any man-made . . . exposure without the expectation of benefit resulting from it," and that "there can be no *single* permissible . . . level . . . without regard to the reason for permitting the exposure." The memorandum therefore offered only a bench mark, a reference point, with which any proposed exposures could be compared. It proposed sets of exposure values that might be accrued over stated time intervals under what it called "normal peacetime operations," one set for radiation workers and another for the general population. The fact that the numbers followed closely the recommendations of the ICRP and the NCRP shows that the same sort of "operations" were here envisioned as governed these two committees over the years—the use of radiation and radioactive materials in industry and research and the development of nuclear power. Both committees and the FRC explicitly ruled out natural background and the intentional use of radiation on patients. By implication, though never stated, fallout from weapon tests was also excluded, since the ICRP and NCRP, at least, clearly intended to deal only with the kinds of peaceful uses I have mentioned. This

implication would not necessarily mean that the guides could not serve a useful purpose in appraising the fallout problem but only that the numbers selected were based on other considerations. One might choose to judge other kinds of operations in the light of these guide numbers or, alternatively, to establish other numbers appropriate to the kinds of operations contemplated. The memorandum seems to favor the latter approach, since it said: "There can be different Radiation Protection Guides with different numerical values, depending upon the circumstances." It also noted "that our present scientific knowledge does not provide a firm foundation within a factor of two or three for selection of any particular numerical value in preference to another value." It might have been more pertinent to comment that our scale of social values is too crude to determine within much larger factors the worth to society of the various beneficial uses of atomic energy and radiation—the quantity that has to be weighed against the risk.

The guides took cognizance of a recommendation in the 1958 ICRP report that the genetically significant dose to the whole population from man-made sources other than medical irradiation should not exceed 5 rems. This number was therefore specified as the guide for average gonadal exposure of the population during a 30-year period, the mean generation time. Note that this means an average of 0.17 rem per year, and many have puzzled over reconciliation of this number with the 0.5 rem of whole-body radiation given as the guide for an individual in the general population. The two are, nevertheless, consistent. The guides recognize that it is not practicable to measure the exposure of every one of our 180 million people to determine conformance with the 0.5-rem guide. Instead, "as an operational technic," if "a suitable sample of the exposed population" has an annual

average of 0.17 rem, almost no one will have received more than three times that amount, or 0.5 rem. There may indeed be a few who fall outside this range of three times the average; but, at this low level of risk—one-tenth that of the radiation worker—their individual chances of harm are truly insignificant; and the purpose of this control measure to restrict the average genetic dose of the population will be achieved.

One point in the memorandum seems to have been overlooked by many, and some misunderstanding may be attributed to that fact. The closing recommendation was "that the Federal agencies apply these. . . . Guides *with judgment and discretion*" and that "the Guides *may be exceeded*," but "only after the Federal agency having jurisdiction over the matter has carefully considered the reason for doing so in light of the recommendations in this paper." For example, the AEC standards of exposure and the corresponding allowable concentrations of radioisotopes in air and water, which antedated the FRC report and were taken bodily from the NCRP recommendations, are not the same as the FRC Guides. Experience has indicated, however, that operations in accordance with the AEC standards result in exposures well below the reference levels of the FRC Guides; and hence it is appropriate for the AEC to maintain, as it does, that it is applying the guides with the prescribed "judgment and discretion." Another example pertains to fallout from nuclear weapons tests; but, before discussing that, let us look at FRC Report No. 2" and its associated "Memorandum for the President."⁹

In this report and memorandum, the Radiation Protection Guides were applied to develop recommendations for the control of intake of certain isotopes of current interest. Radium was one of these, probably not only because of its widespread natural occurrence and the

fact that its localization in bone adds to the effects of other bone-seekers to be considered, but also because many years ago our ignorance of its effects gave us, by accident, one of the few samples of humans exposed at harmful levels and hence gave us a basis for judging guide levels for bone-seeking radioisotopes. The other isotopes considered were the bone-seekers strontium-89 and -90, which occur as residues from weapon tests, and iodine-131, which is a short-lived fission product that may enter the environment not only from weapon tests but also from such procedures as chemical processing of fuel removed from reactors.

The memorandum recommended numerical exposure guides to "be adopted for normal peacetime operations" for the general population with respect to doses to bone and marrow, relating the guides to the carcinogenic effect on the bone itself and on the blood-forming structures in the marrow. It also recommended a guide for the thyroid, in which iodine localizes. In both cases, it took cognizance of the presence of young children in the general population and the special characteristics of that group which tend to require more restrictive conditions than for adults. Inclusion of the strontium isotopes, in particular, which are very unlikely to enter the general environment except through weapon tests, strongly suggests that the FRC staff had fallout in mind when preparing the report, even though the chairman of the FRC has stated that the guides were developed with reference to "the industrial use of ionizing radiation."¹⁰ He does acknowledge, however, that the guides may serve as one of a number of criteria to evaluate the related fallout problem.

To treat the problem of these internally absorbed radioisotopes, the bone and marrow and thyroid exposure guides were converted to equivalent continuous daily intakes of radium, stron-

tium-89 and -90, and iodine-131. These intake guide levels were then related to appropriate courses of action, graded in three steps of increasing stringency for increasing levels of intake. The lowest level, Range I, requires no special action. In Range II, the customary surveillance should be supplemented by more detailed analyses, and the customary control measures to limit the exposure should be more energetically applied. Range III covers intakes above the guide level, and hence requires more thorough evaluation of the situation to determine how long the higher level is likely to continue, whether further measures to control the primary source are feasible, what measures are available to reduce the relative intake by people from a given environmental concentration, and so on, and to decide what actions, if any, to take in the light of their difficulty, their other effects on health, their cost, etc. Range I extends from zero to one-tenth the guide level; Range II, from one-tenth to the guide level; and Range III, from the guide level to ten times that level. Nothing was said of higher levels, but obviously they would be dealt with as an intensification of the urgency of the actions appropriate to Range III. It is interesting to note that the strontium levels were lowered by a factor of 3 from what the exposure guides indicated, just because "there is currently no known operational requirement for an intake value as high as the one corresponding to the RPG." Here, at least, the staff must have focused their attention on industrial activities.

The key question has revolved about what to do in Range III. No "normal peacetime operations" have ever come close to delivering such amounts of these radioisotopes to large numbers of people for great lengths of time, nor are they expected to; but test fallout could. Note the importance of the *large* population and the *long* time, since these are what fixed the low levels of these guides. The

basis of calculation involved lifetime exposures, beginning at birth, so that a thousand times the guide level presents less than the reference level of risk if it continues for only a few days and is preceded or followed by several years of essentially zero level. To form as practical a basis for judgment as possible, it was recommended that, in applying the guides, an estimate of the situation be based on periods of the order of a year, since it would be meaningless to guess what would happen over several decades and unwise to take hasty action if the troublesome situation seemed likely to persist for only a short time. And if the high levels affected only a small number of people, the chance of harming one of them would be small.

There is not, nor is there ever likely to be, any simple rule that will determine whether to take action or what action to take when Range III is reached and maintained for a time, since the answer depends not only on duration and population but on a multiplicity of other factors. If the difficulty can be readily stopped at the source of the environmental contamination, as for normal peaceful uses of atomic energy, the answer is relatively simple; but how do we apply the criterion to nuclear weapon testing? Remember that "the guides may be exceeded" for good reason; and if our national defense is indeed enhanced by testing, the justification is clear. If we phrase the question, "Should we stop nuclear testing?" the answer is that fallout is of negligible importance compared with the main issue. If weapon testing has any national defense significance at all, it either increases or decreases the chance of nuclear war. No matter how small that change in the risk of war, that small probability of incurring or avoiding many tens of millions of immediate deaths, an even greater number of serious injuries, and residual radiation ef-

fects worldwide at levels hundreds of times those of testing makes the comparative effects of test fallout completely negligible in reaching the right conclusion. The only meaningful question is, "Should we take steps to counteract the effects of test fallout?" and then the variability of fallout effects, of local food supply and consumption, of transportation and other factors on which some countermeasures depend are among the considerations that make the answer locally variable.

Even levels at the top of Range III and above present no serious immediate threat to health of the individual, so that countermeasures may be considered calmly and judiciously. Steps such as placing cattle on stored feed in a locality where iodine-131 levels are high seem sensible if plans have been made for such action, so that it is not taken in an atmosphere of panic that may not only disrupt dairy operations but may cause needless worry by parents of young children. On the other hand, radical changes of children's diets probably do much more harm than good. The present test ban reduces the urgency of finding either local or national answers; but it is wise to continue our studies of the problem and preparations for steps to take if required.

Conclusion

I will close, however, by cautioning against loss of perspective in considering

the problems of controlling radiation exposure. At the Joint Committee on Atomic Energy (JCAE) hearings last year, I offered the estimate that, with the levels of strontium-90 then found in milk, the estimated cost to remove it, and the more adverse estimates of how many leukemia cases might be caused per strontium unit, the cost per leukemia case theoretically averted would be of the order of a billion dollars. Current process cost estimates seem to be down by a factor of 11, so I would revise my estimate to, say, 100 million dollars per theoretical leukemia case. And I still say that many more lives than one can surely be saved by spending that much money on other public health activities.

REFERENCES

1. Buck, Carol. Population Size Required for Investigating Threshold Dose in Radiation-Induced Leukemia. *Science* 129:1357 (May), 1959.
2. U. S. Department of Commerce, National Bureau of Standards. Permissible Dose from External Sources of Ionizing Radiation—Handbook 59. Addendum dated (Apr. 15), 1958. Washington, D. C.: Supt. of Documents.
3. National Academy of Sciences. The Biological Effects of Atomic Radiation—Summary Reports. p. iii. Washington, D. C.: National Research Council, 1956.
4. *Ibid.*, p. 39.
5. *Loc. cit.*, ref. 2, pp. 20-21.
6. Recommendations of the International Commission on Radiological Protection. Adopted September 9, 1958, p. 15. New York, N. Y.: Pergamon Press, 1959.
7. Public Law 86-373.
8. 25 Federal Register 4402 (May 18), 1960.
9. Reprint from the Federal Register of September 26, 1961, as corrected. Available from Federal Radiation Council, Washington, D. C.
10. Letter, August 17, 1962, Chairman Celebrezze to Congressmen Hollifield and Price. In "Radiation Standards, Including Fallout." Part 2—Appendix, JCAE Hearings, June, 1962, pp. 584-586.

Mr. Grendon is associated with the Donner Laboratory, University of California, Berkeley, Calif.

This paper was presented before the Fourth General Session, Association Symposium, of the American Public Health Association at the Ninety-First Annual Meeting in Kansas City, Mo., November 15, 1963.